

# Is the X-ray variable source in M82 due to gravitational lensing ?

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## ABSTRACT

We explore the possibility of attributing the recent discovery of the hard X-ray variable source CXOM82 J095550.2+694047 in M82 to the gravitational magnification by an intervening stellar object along the line of sight as microlens. The duration of the event ( $> 84$  days) allows us to set robust constraints on the mass and location of the microlensing object when combined with the dynamical properties of the Galactic halo, the M82 and typical globular clusters. Except for the extremely low probability, the microlensing magnification by MACHO in either the Galactic halo or the M82 halo is able to explain the X-ray variability of CXOM82 J095550.2+694047. It is hoped that the lensing hypothesis can be soon tested by the light curve measurement.

## 1. Introduction

Observations of the most famous starburst galaxy M82 with the High-Resolution Camera on board the *Chandra X-Ray Observatory*, show that there are nine sources in the central  $1' \times 1'$  region, but no source was detected at the galactic center (Matsumoto et al. 2001). Comparing the observations on 1999 October 28 and on 2000 January 20, the authors found an extremely large time variability of the source CXOM82 J095550.2+694047, which is  $9''$  away from the galactic center. They concluded that this source is the origin of the hard X-ray time variability of M82 detected with ASCA. Assuming a spectral shape obtained by the ASCA observation, its luminosity in the 0.5 - 10 KeV band changed from  $1.2 \times 10^{40}$  erg s $^{-1}$  on 1999 October 28 to  $8.7 \times 10^{40}$  erg s $^{-1}$  on 2000 January 20.

It is difficult to explain such a short-term variability in terms of a supernova remnant. If the spectral shape of the source is described by an absorbed thermal bremsstrahlung model, the observations show that the probability of such a bright source existing in the  $1' \times 1'$  field is 0.3%. Consequently, this source is probably not a background AGN.

CXOM82 J095550.2+694047 may be a medium-massive black hole (Matsumoto et al. 2001), and the possibilities that an X-ray binary source whose jet is strongly beamed towards us cannot be excluded. In this letter, we explore an alternative possibility that the time variability of the source is originated from the microlensing effect by MACHO along the line of sight.

## 2. Microlensing explanation

The source CXOM82 J095550.2+694047 is  $9''$  away from the center of M82 (its distance from us is 3.9 Mpc). It may be located in a star cluster with typical size of 2.34 - 10 pc (de Grijs et al. 2001) and typical velocity dispersion of member stars of 15 km/s.

If a foreground star is traversing across the line of sight, the apparent magnitude of the source would be magnified according to microlensing theory. The duration of the crossing time is  $T = 2a_E/v$ , in which  $a_E$  is the Einstein radius defined as

$$a_E = \left( \frac{4GM}{c^2} \frac{D_{ds}D_d}{D_s} \right)^{1/2}, \quad (1)$$

where  $D_d$ ,  $D_s$  and  $D_{ds}$  are the angular diameter distances to the lens, to the source and from the lens to the source, respectively,  $v$  is the relative velocity perpendicular to the line of sight between the source and the lens.

The mass of microlens is related to the crossing time as (Wu 1996)

$$M = \frac{c^2}{32G} \frac{D_s}{D_d D_{ds}} \frac{v^2 T^2}{0.4919}, \quad (2)$$

where we have chosen the total maximum magnification to be  $\mu_T = 7.0$ , since the luminosity of the source in the 0.5 - 10 KeV band changed from  $1.2 \times 10^{40}$  erg s $^{-1}$  on 1999 October 28 to  $8.7 \times 10^{40}$  erg s $^{-1}$  on 2000 January 20.

A microlens of mass of  $\sim M_\odot$  could lie at any point between the source and the observer, and different positions would lead to different crossing time. For the source CXOM82 J095550.2+694047, the observed time duration must exceed 84 days. For simplicity, we can take  $T = 2 \times 84$  days for an approximate estimate. The microlens mass versus its distance is plotted in Fig.1 for three kinds of lensing models: the microlens is located in our Galaxy with a typical velocity of 200km/s, in M82 with a typical velocity of 100km/s and in the star cluster of the source with a velocity of 15km/s.

At three different positions of a microlens in the Galaxy, the M82 and the star cluster of the source, the same microlens mass would lead to different crossing time durations, as is shown in Fig.2. We set  $D_s = 3.9$ Mpc in all the panels. Because of the symmetry between  $D_d$  and  $D_{ds}$  in equation (2), the first and second panels both in Fig.1 and Fig.2 look very similar.

## 3. Discussions and conclusions

It can be seen clearly from Fig.1 and Fig.2 that the microlens object, if any, should be located in M82 or the Galactic halo. However, we can exclude the possibility of the self-lensing by a star in the star cluster where CXOM82 J095550.2+694047 may be harbored if the typical size of a star cluster is smaller than  $\sim 10$  pc.

The probability that a source is gravitationally lensed is described by the optical depth which amounts to  $\sim 10^{-6}$ . Indeed, the event like the hard X-ray variable source CXOM82 J095550.2+694047 seen in M82 is very rare if it is due to microlensing. A conclusive resolution needs a detailed sample of the light curve of CXOM82 J095550.2+694047. Whether or not the light curve demonstrates the time-symmetry around the maximum intensity will be a crucial test for the lensing hypothesis.

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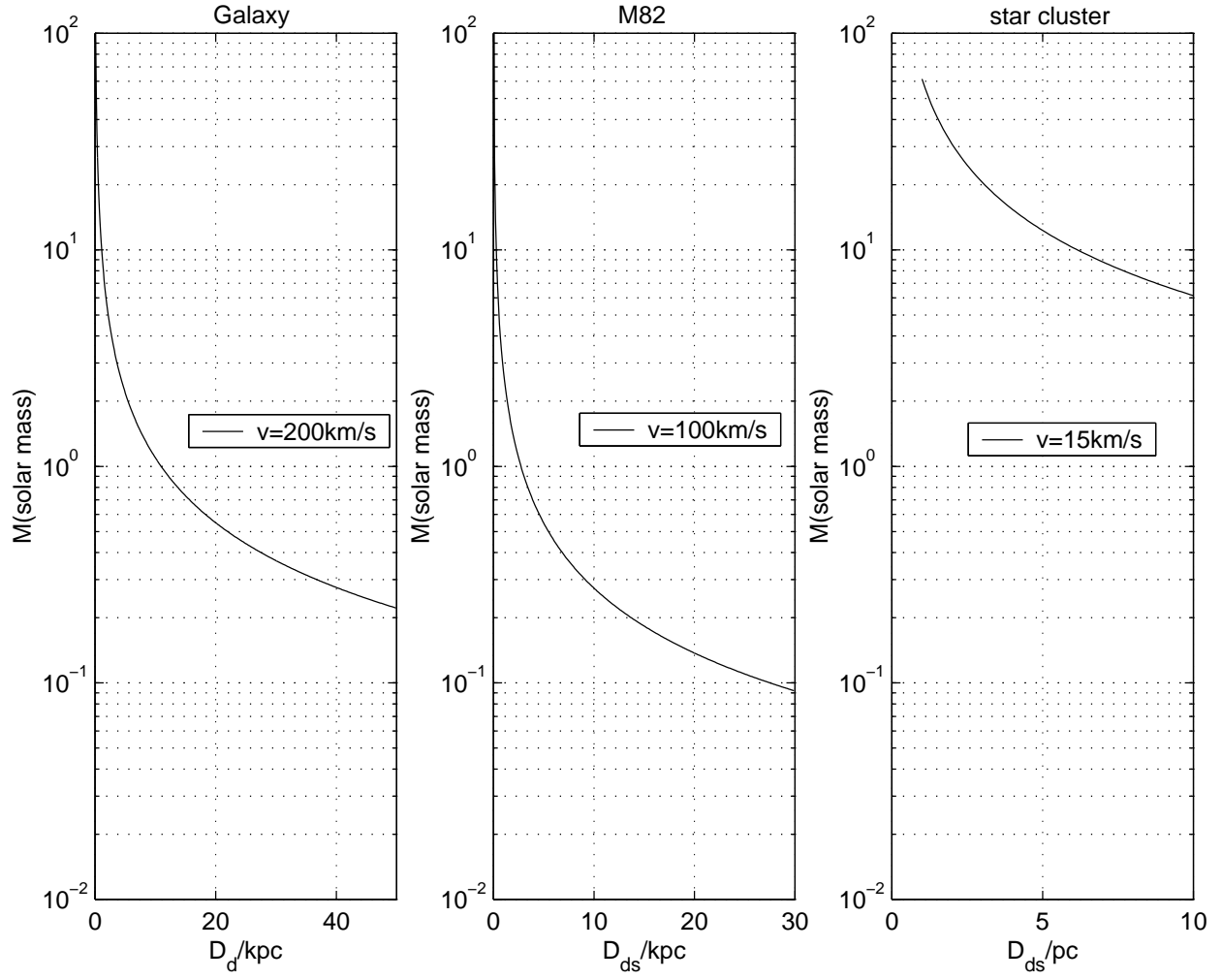


Fig. 1.— The mass of microlens as a function of  $D_d$  or  $D_{ds}$ . Three panels from left to right refer to the positions of lenses located in our Galaxy, in the M82 and in a star cluster, respectively. The corresponding typical velocity of the microlens is clearly marked.

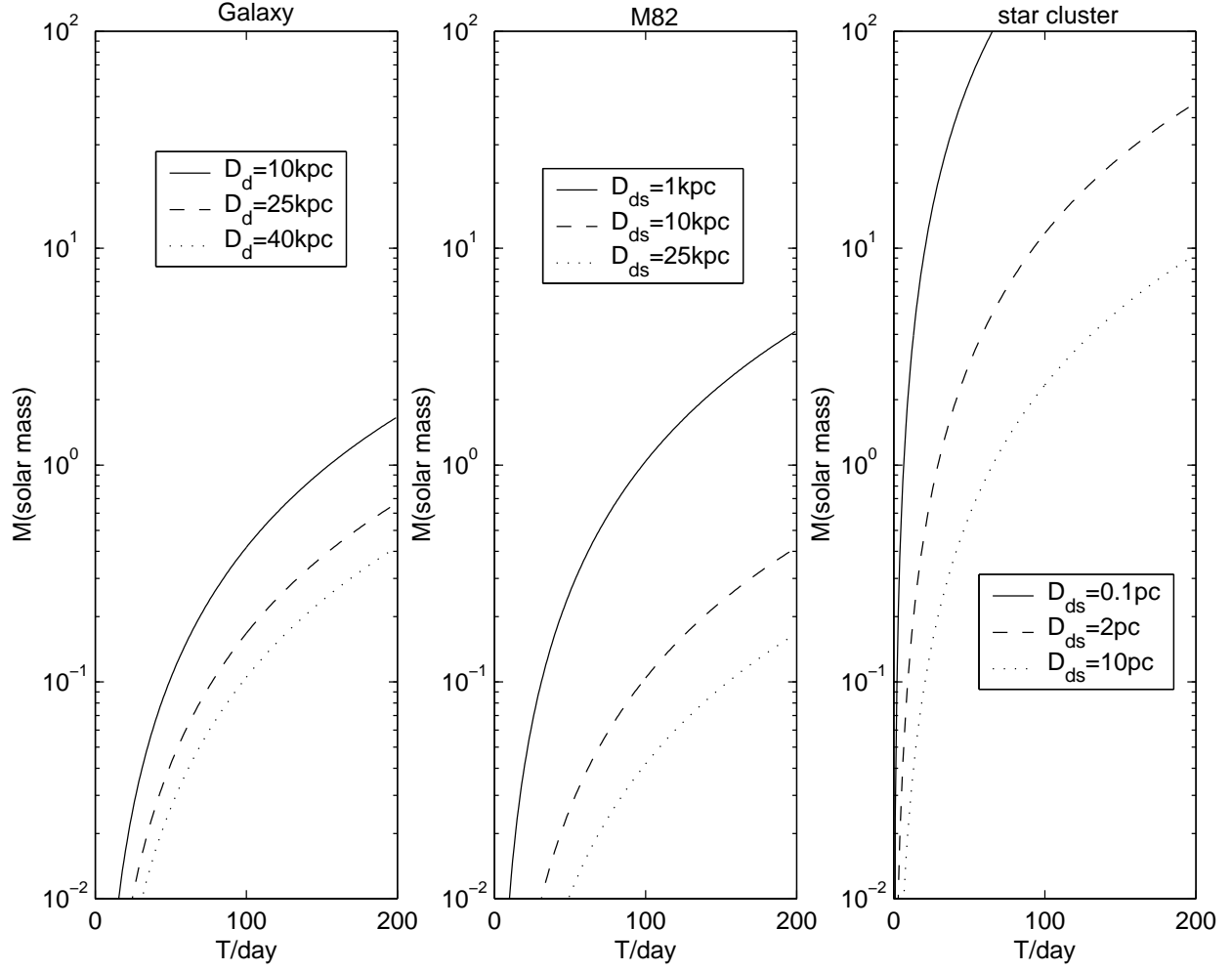


Fig. 2.— The mass of microlens as a function of crossing time duration  $T$ . Three panels from left to right refer to the positions of lenses located in our Galaxy, in the M82 and in a star cluster, respectively. The position of the microlens in each case is also indicated.